DESCRIPTION

SUBSTRATE FOR LIQUID CRYSTAL DEVICE AND METHOD FOR FABRICATING THE SAME, LIQUID CRYSTAL DEVICE AND METHOD FOR FABRICATING THE SAME, AND ELECTRONIC APPARATUS

Technical Field

The present invention relates to substrates for liquid crystal devices and to methods for fabricating the same, to liquid crystal devices and to methods for fabricating the same, and to electronic apparatuses.

Background Art

Liquid crystal display devices capable of performing reflective display have been widely used. In such liquid crystal devices, external light, such as natural light or indoor lighting, enters from the front (from the side of the viewer), and the light is reflected by a reflecting film so as to perform reflective display. In such a structure, since a backlight is not required, power consumption can be minimized, which is advantageous.

If the surface of the reflecting film is specularly reflective, the background, indoor lighting, etc., are also reflected and form images visible to the viewer; thus, the displayed image becomes difficult to see. Therefore, a structure is generally used in which the surface of the reflecting film is roughened so that reflected light is appropriately scattered.

Conventionally, such a scattering structure is fabricated as described below. That is, first, the surface of a substrate composed of a glass or the like is ground using an abrasive, and numerous microscopic peaks and valleys are formed. The reflecting film described above is formed on the roughened surface, and thus the surface of the reflecting film is also rough because it is affected by the surface of the glass substrate. Consequently, light reflected by the reflecting film is appropriately scattered.

However, in the method described above, since the entire surface of the glass substrate is roughened, alignment marks, switching elements, etc., which are to be formed on a planar surface, must be formed on the roughened surface.

In order to yield satisfactory scattering characteristics, peaks and valleys are preferably formed irregularly in the roughened surface. However, in the method for grinding the substrate using the abrasive, peaks and valleys may be formed regularly, depending on the particle size of the abrasive, the grinding direction, etc. Therefore, it is difficult to obtain satisfactory scattering characteristics in the method described above.

As described above, when the scattering structure is formed using the conventional method, various problems may arise.

Disclosure of Invention

The present invention has been made in view of the situation described above. Objects of the present invention are to provide a

substrate for a liquid crystal device in which adverse effects on the liquid crystal device resulting from roughening of the surface of the substrate can be reduced, a method for fabricating the same, a liquid crystal device, a method for fabricating the same, and an electronic apparatus.

In order to achieve objects described above, in accordance with the present invention, a substrate for a liquid crystal device is one of a pair of substrates having a liquid crystal layer interposed therebetween, the substrate located on the side opposite to the side of the viewer. The surface of the substrate on the side of the liquid crystal layer includes a planar region and a roughened region in which microscopic peaks and valleys are formed, and the heights of the tops of the peaks in the roughened region are equal to or lower than the level of the plane including the planar region.

In such a substrate for a liquid crystal device, since the roughened region and the planar region are selectively formed, a reflecting film having satisfactory scattering characteristics can be formed in the roughened region, and also, for example, elements which are desirably formed in a planar state can be formed in the planar region.

In view of the cell gap, etc., of the liquid crystal device, preferably, the difference in level between the planer region and the roughened region is 5 μm or less.

In order to obtain satisfactory scattering characteristics, in general, the peaks and valleys in the roughened region are preferably

formed irregularly. Specifically, the roughened region is preferably formed so that the individual peaks have different heights or the individual valleys have different depths and the distance between the top of one peak and the top of an adjacent peak differs for each peak. When regular peaks and valleys are formed, reflected light may be colored due to optical-path differences depending on the reflection angle, resulting in degradation of display characteristics.

In accordance with the present invention, a predetermined mark may be formed in the planar region. Examples of the predetermined mark include an alignment mark and a process control mark. By forming such a mark in the planar region, the mark can be reliably detected, in contrast to the case in which the mark is formed in the roughened region.

Examples of the alignment mark include an alignment mark for aligning the substrate for the liquid crystal device relative to another substrate when they are to be bonded together. In addition, alignment marks used for forming switching elements, pixel electrodes, etc., for forming color filters or shading layers, for applying alignment films, for printing a sealant, for cutting a panel, or for mounting a semiconductor integrated circuit for driving the liquid crystal device may be formed in the planar region.

Examples of the process control mark include marks for indicating lot numbers, model numbers, treatment conditions in various fabrication processes, etc. As other examples of process control marks, various types of information may be digitized, encoded into bar codes, or printed in the form of two-dimensional bar codes, such as verified-codes.

In accordance with the present invention, wiring may be formed in the planar region. Herein, "wiring" conceptually includes, for example, lines such as scanning lines and data lines in an active matrix liquid crystal device, switching elements, such as TFTs (Thin Film Transistors) and TFDs (Thin Film Diodes), and terminals of a semiconductor integrated circuit for driving a liquid crystal. If such wiring is formed in the planar region, variations in characteristics of the individual elements can be reduced compared to the case in which the wiring is formed in the roughened region.

In accordance with the present invention, a sealant may be formed in the planar region. The sealant generally contains spherical or rod-like spacers of predetermined diameter in order to maintain space between the substrates, and when the sealant is formed on a roughened surface, the function of the spacers is not adequate. Additionally, a plurality of the individual elements described above or other elements may be formed in the planar region.

In accordance with the present invention, preferably, the maximum height Ry, the arithmetic mean roughness Ra, the ten-point average roughness Rz, and the mean wavelength Sm in the roughened region are in the predetermined ranges. That is, the surface profile of the roughened region is preferably formed so that a desired reflection property is obtained by the reflecting film formed in the roughened region. Specifically, the combination of the maximum height Ry, the arithmetic mean roughness Ra, the ten-point average roughness Rz, and the mean wavelength Sm in the roughened region is preferably set as follows.

First, preferably, the maximum height Ry is set at 0.2 to 3 μm, the arithmetic mean roughness Ra is set at 0.02 to 0.3 μm, the ten-point average roughness Rz is set at 0.1 to 2.5 μm, and the mean wavelength Sm is set at 4 to 60 μm. Alternatively, the maximum height Ry may be set at 1.5 to 2.0 μm, the arithmetic mean roughness Ra may be set at 0.15 to 0.3 μm, the ten-point average roughness Rz may be set at 1.3 to 1.8 μm, and the mean wavelength Sm may be set at 15 to 25 μm.

Furthermore, the maximum height Ry may be set at 0.7 to 1.2 μm, the arithmetic mean roughness Ra may be set at 0.1 to 0.2 μm, the ten-point average roughness Rz may be set at 0.5 to 1.0 μm, and the mean wavelength Sm may be set at 35 to 50 μm. Alternatively, the maximum height Ry may be set at 0.6 to 1.2 μm, the arithmetic mean roughness Ra may be set at 0.05 to 0.15 μm, the ten-point average roughness Rz may be set at 0.5 to 1.0 μm, and the mean wavelength Sm may be set at 15 to 25 μm.

Furthermore, the maximum height Ry may be set at 0.4 to 1.0 μm, the arithmetic mean roughness Ra may be set at 0.04 to 0.10 μm, the ten-point average roughness Rz may be set at 0.3 to 0.8 μm, and the mean wavelength Sm may be set at 8 to 15 μm. Alternatively, the maximum height Ry may be set at 0.8 to 1.5 μm, the arithmetic mean roughness Ra may be set at 0.05 to 0.15 μm, the ten-point average roughness Rz may be set at 0.7 to 1.3 μm, and the mean wavelength Sm may be set at 8 to 15 μm.

In general, in a liquid crystal device using a STN (super twisted nematic) liquid crystal mode, the viewing angle over which satisfactory

display characteristics with a high contrast ratio can be obtained is limited to a relatively narrow angle. That is, it is not required that reflected light be scattered to a wide viewing angle range over which visibility is decreased in principle. Therefore, with respect to the liquid crystal device using the STN liquid crystal mode, it is desirable that a reflecting film having a reflection property of limiting reflected light to a relatively narrow range be used. Consequently, when the substrate for the liquid crystal device in accordance with the present invention is used for a liquid crystal device using the STN liquid crystal mode, the surface profile of the substrate is preferably determined so that a reflecting film formed on the substrate has the reflection property described above. Specifically, in the STN liquid crystal mode in which a slight shift in the thickness of the liquid crystal layer may significantly affect the display quality, preferably, the maximum height Ry and the ten-point average roughness Rz are as minimized as possible and the mean wavelength Sm is decreased. In this way, thickness deviations of the liquid crystal layer resulting from the peaks and valleys in the roughened region can be suppressed and desired scattering characteristics can be obtained. Furthermore, by decreasing the arithmetic mean roughness Ra, thickness deviations in the liquid crystal layer in response to in-plane undulations can be suppressed.

On the other hand, in a liquid crystal device using a TN (twisted nematic) liquid crystal mode, a TN mode combined with a quarter-wave plate, or a SH (superhomeotropic) liquid crystal mode, the viewing angle in which satisfactory display characteristics with a high contrast ratio

can be obtained is relatively wide. Therefore, in a liquid crystal device using such a liquid crystal mode, it is desirable that a reflecting film having a reflection property of scattering strong reflected light over a relatively wide range be used. Specifically, in the substrate for the liquid crystal device in accordance with the present invention, by implementing at least one of an increase in the ten-point average roughness Rz and a decrease in the mean wavelength Sm, the reflection property described above can be imparted to the reflecting film formed on the substrate. In the liquid crystal device using such a liquid crystal mode, although the effect of the thickness deviation of the liquid crystal layer on the display characteristics is decreased in comparison with the STN liquid crystal mode, the mean wavelength is preferably as short as possible.

Furthermore, in order to overcome the problems described above, in a liquid crystal device in accordance with the present invention, a liquid crystal layer is interposed between any one of the substrates for the liquid crystal devices described above and a counter substrate. In such a liquid crystal device, for example, by an alignment mark formed in the planar region of the substrate for the liquid crystal device, alignment with the counter substrate can be performed with high accuracy and satisfactory display characteristics can be obtained by appropriately selecting the shape of the roughened region in response to the liquid crystal mode used in the liquid crystal device. Additionally, the present invention is also applicable to an electronic apparatus provided with the liquid crystal device described above.

In order to overcome the problems described above, in accordance with the present invention, a method for fabricating a liquid crystal device having a liquid crystal layer interposed between a pair of substrates, includes the steps of covering, with a mask, a portion of the liquid crystal layer side surface of the substrate located opposite to the side of the viewer; roughening a region of the surface, excluding the region covered by the mask, to form a roughened region having microscopic peaks and valleys, in which the heights of the tops of the peaks are equal to or lower than the level of the plane including the region covered by the mask; and bonding the pair of substrates together so that the surface of one substrate provided with the roughened region is opposed to the other substrate. In the substrate for the liquid crystal device obtained by the method described above, the same effect as that described above can be obtained.

As the mask, a photoresist, a resin adhesive, such as an epoxy resin, a coating material, or the like may be used. When such a material having high adhesion to a substrate is used as the mask, the boundary between the region covered by the mask and the other region can be defined. In particular, when the region corresponding to the display area of the liquid crystal device is arranged as an opening of the mask, by defining the boundary between the planar region and the roughened region, a space between the display area and an area for forming a sealant can be narrowed, and thus the ratio of the display area to the entire surface of the liquid crystal device can be increased. Additionally, the photoresist, the resin adhesive, the coating material,

etc., can be easily removed using an alkaline solution, an organic solvent, etc.

When the material described above is used for the mask, the mask is preferably printed on the substrate using a printing plate, such as a flexographic plate or a mesh plate. In this way, the mask can be accurately formed in the desired region. In addition, the mask may be formed using a direct patterning device, such as a dispenser or an ink jet nozzle. In this way, the fabrication cost can be reduced because it is not necessary to form a different printing plate for each model of liquid crystal device. Also, since a drawing of a predetermined shape can be easily made, this method is preferable when a planar region having a special shape is formed.

The material for the mask is not limited to the resin material, etc., described above. For example, a fusible film or a film applied with an adhesive which is cut into a predetermined shape may be used as the mask by transfer printing. In this way, a mask can be formed using a very inexpensive material, such as a laminated film, by a simple process.

In the fabrication method described above, preferably, one of the pair of substrates contains a first composition which is network-shaped and a second composition located in spaces of the network of the first composition, and when roughening is performed, by etching the substrate using a treatment solution having different dissolution rates for the first composition and the second composition, the peaks and valleys in response to the shape of the first composition are formed in regions

other than the region covered by the mask. In this way, when the region not covered by the mask is roughened, the roughened region can be formed without using an expensive apparatus, such as an apparatus provided with an evacuation system or an exposure apparatus. Additionally, as the treatment solution, for example, any one of nitric acid, sulfuric acid, hydrochloric acid, hydrogen peroxide, ammonium hydrogen difluoride, ammonium fluoride, ammonium nitrate, ammonium sulfate, and ammonium hydrochloride, and so on may be used alone or in combination at an appropriate and predetermined ratio in accordance with the material for the substrate for the liquid crystal device to be treated. As the substrate for the liquid crystal device, for example, soda-lime glass, borosilicate glass, barium borosilicate glass, barium aluminosilicate glass, or aluminosilicate glass may be used. In general, when the substrate for the liquid crystal device is treated using a hydrofluoric acid solution alone, the entire surface of the substrate is uniformly etched, and thus it is not possible to form a roughened surface. However, by appropriately adding an auxiliary agent which selectively dissolves a constituent contained in the substrate for the liquid crystal device, a roughened region having many microscopic peaks and valleys can be formed. Additionally, the auxiliary agent to be mixed with the treatment solution is not limited to that described above. Preferably, the types of the treatment solution and the mixing ratio are appropriately selected depending on the material of the substrate for the liquid crystal device to be treated.

In the fabrication method described above, when roughening is

performed, granular members may be made to impact the surface of one of the substrates through the mask so that the peaks and valleys are formed in regions other than the regions covered by the mask. That is, a so-called "sandblasting" treatment is carried out on the surface of one of the substrates. Herein, as the mask, for example, a metal plate composed of a stainless steel provided with openings may be used. Since such a mask is usually inexpensive and durable, the fabrication cost can be greatly reduced. Furthermore, since the mask can be easily detached after the sandblasting treatment, an additional step of removing the mask is not required.

In the individual fabrication methods described above, preferably, after the roughening treatment, the mask is removed and the region which had been covered by the mask and the roughened region are subjected to etching. By such etching, the form of the roughened region can be adjusted as desired. Herein, if such etching is performed before the mask is removed, the difference in level between the roughened region and the planar region will be increased. As a result, if the difference in level is larger than the desired cell gap of the liquid crystal device, it is not possible to use the substrate for the liquid crystal device. In contrast, by uniformly etching both the roughened region and the planar region after the mask is removed, an increase in the difference in level between the two can be minimized.

In accordance with the present invention, a method for fabricating a substrate for a liquid crystal device, the substrate being one of a pair of substrates having a liquid crystal layer interposed therebetween,

includes the steps of covering, with the mask, a portion of the liquid crystal layer side surface of the substrate located opposite to the side of the viewer; and roughening a region of the surface other than the region covered by the mask to form a roughened region having microscopic peaks and valleys, in which the heights of the tops of the peaks are equal to or lower than the level of the plane including the region covered by the mask. In this fabrication method, the same effects as those in the method for fabricating the liquid crystal device described above can also be obtained.

In the method for fabricating the substrate for the liquid crystal device, the substrate for the liquid crystal device may contain a first composition which is network-shaped and a second composition located in spaces of the network of the first composition, and when the roughening treatment is performed, by etching the substrate using a treatment solution having different dissolution rates for the first composition and the second composition, the peaks and valleys in response to the shape of the first composition are formed in the region other than the region covered by the mask. Alternatively, when the roughening treatment is performed, granular members may be made to impact the surface of the substrate for the liquid crystal device through the mask so that the peaks and valleys are formed in regions other than the regions covered by the mask.

In the method for fabricating the substrate for the liquid crystal device, preferably, after the roughening treatment, the mask is removed and the regions which had been covered by the mask and the roughened

regions are also subjected to etching.

Brief Description of the Drawings

Fig. 1A is a plan view illustrating a state in which a photoresist is formed on a glass substrate in the fabrication process of a liquid crystal display device in a first embodiment of the present invention.

Fig. 1B is a sectional view taken along the line A-A' of Fig. 1A.

Fig. 1C is a sectional view illustrating a state in which the surface of the glass substrate is roughened in the fabrication process of the liquid crystal display device in the first embodiment of the present invention.

Fig. 1D is a sectional view illustrating a state in which the photoresist is removed in the fabrication process of the liquid crystal display device in the first embodiment of the present invention.

Fig. 1E is a sectional view illustrating a state in which a metal film is formed on the glass substrate in the fabrication process of the liquid crystal display device in the first embodiment of the present invention.

Fig. 1F is a sectional view illustrating a state in which a reflecting film and an alignment mark are formed on the glass substrate in the fabrication process of the liquid crystal display device in the first embodiment of the present invention.

Fig. 2 is an optical micrograph of the alignment mark formed in the planar region on the glass substrate.

Fig. 3A is a plan view illustrating a state in which a photoresist

is formed on a glass substrate in the fabrication process of a liquid crystal display device in a second embodiment of the present invention.

Fig. 3B is a sectional view taken along the line B-B' of Fig. 3A.

Fig. 3C is a sectional view illustrating a state in which the surface of the glass substrate is roughened in the fabrication process of the liquid crystal display device in the second embodiment of the present invention.

Fig. 3D is a sectional view illustrating a state in which the photoresist is removed in the fabrication process of the liquid crystal display device in the second embodiment of the present invention.

Fig. 3E is a sectional view illustrating a state in which a metal film is formed on the glass substrate in the fabrication process of the liquid crystal display device in the second embodiment of the present invention.

Fig. 3F is a sectional view illustrating a state in which a reflecting film and an alignment mark are formed on the glass substrate in the fabrication process of the liquid crystal display device in the second embodiment of the present invention.

Fig. 4A is a plan view illustrating a state in which a laminated film is formed on a glass substrate in the fabrication process of a liquid crystal display device in a third embodiment of the present invention.

Fig. 4B is a sectional view taken along the line C-C' of Fig. 4A.

Fig. 4C is a sectional view illustrating a state in which the surface of the glass substrate is roughened in the fabrication process

of the liquid crystal display device in the third embodiment of the present invention.

Fig. 4D is a sectional view illustrating a state in which the laminated film is removed in the fabrication process of the liquid crystal display device in the third embodiment of the present invention.

Fig. 4E is a sectional view illustrating a state in which a metal film is formed on the glass substrate in the fabrication process of the liquid crystal display device in the third embodiment of the present invention.

Fig. 4F is a sectional view illustrating a state in which a reflecting film and an alignment mark are formed on the glass substrate in the fabrication process of the liquid crystal display device in the third embodiment of the present invention.

Fig. 5A is a sectional view which schematically shows the structure of a glass substrate.

Fig. 5B is a sectional view illustrating a state in which a mask is formed in a first method for fabricating a substrate for a liquid crystal display device of the present invention.

Fig. 5C is a sectional view illustrating a state in which a glass substrate is subjected to first etching in the first fabrication method.

Fig. 5D is a sectional view illustrating a state in which the mask on the glass substrate is removed in the first fabrication method.

Fig. 5E is a sectional view illustrating a state in which the glass substrate is subjected to second etching in the first fabrication method.

Fig. 6A is an optical micrograph showing the surface of the glass

substrate after first etching in the first fabrication method.

Fig. 6B is an optical micrograph showing the surface of the glass substrate after the second etching in the first fabrication method.

Fig. 7 is an optical micrograph showing the roughened region formed by the first fabrication method and the planar region.

Fig. 8 is a graph showing measurement results of the height in the roughened region formed by the first fabrication method and the planar region.

Fig. 9A is a sectional view which schematically shows the structure of a glass substrate.

Fig. 9B is a sectional view illustrating a state in which a mask is formed on the glass substrate in a second method for fabricating a liquid crystal display device of the present invention.

Fig. 9C is a sectional view illustrating a state in which etching is performed in the second fabrication method.

Fig. 9D is a sectional view illustrating a state in which etching is finished in the second fabrication method.

Fig. 9E is a sectional view illustrating a state in which the mask on the glass substrate is removed in the second fabrication method.

Fig. 10A is a plan view illustrating a state in which a stainless steel plate is placed on a glass substrate in a third method for fabricating a substrate for a liquid crystal display device of the present invention.

Fig. 10B is a sectional view taken along the line D-D' of Fig. 10A.

Fig. 10C is a sectional view illustrating a state in which abrasive

powder is sprayed to the surface of the glass substrate in the third fabrication method.

Fig. 10D is a sectional view illustrating a state in which a planar region and a roughened region are formed on the glass substrate in the third fabrication method.

Fig. 10E is a sectional view illustrating a state in which a metal film is formed on the glass substrate in the third fabrication method.

Fig. 10F is a sectional view illustrating a state in which a reflecting film and an alignment mark are formed on the glass substrate in the third fabrication method.

Fig. 11 is an enlarged sectional view which shows a roughened surface of a conventional substrate for a liquid crystal device.

Fig. 12 is a schematic diagram which shows the structure of a measuring device for measuring the reflection property of a substrate for a liquid crystal device in accordance with the present invention.

Fig. 13 is a graph which shows the reflection properties of substrates for liquid crystal devices in accordance with the present invention.

Fig. 14 is a sectional view which shows a structure of a liquid crystal device using a substrate for a liquid crystal device in accordance with the present invention.

Fig. 15 is a sectional view which shows another structure of a liquid crystal device using a substrate for a liquid crystal device in accordance with the present invention.

Fig. 16A is a perspective view of a notebook personal computer

using a liquid crystal device in accordance with the present invention.

Fig. 16B is a perspective view of a mobile communication terminal using a liquid crystal device in accordance with the present invention.

Fig. 16C is a perspective view of a watch using a liquid crystal device in accordance with the present invention.

Best Mode for Carrying Out the Invention

The embodiments of the present invention will be described with reference to the drawings.

A: Substrate for Liquid Crystal Device

In a substrate for a liquid crystal device in accordance with the present invention, a roughened region and a planar region are formed on the surface facing a liquid crystal layer. Herein, a "roughened region" is a region in which the surface has many microscopic protrusions and recesses. Hereinafter, each microscopic protrusion in the roughened region is referred to as a peak, and each microscopic recess in the roughened region is referred to as a valley. A "planar region" is a region in which the surface is planar. As a detailed description will be given below, in the substrate for the liquid crystal device in accordance with the present invention, alignment marks, switching elements, etc., are formed in the planar region of one of the surfaces. First, the shape of the planar region for forming the individual elements, as well as the outline of the fabrication method thereof, will be described below. Additionally, in the following embodiments, it is assumed that 4 substrates for liquid crystal devices are formed on one

glass substrate.

A-1: First Embodiment

A method for fabricating a substrate for a liquid crystal device in a first embodiment of the present invention will be described with reference to Figs. 1A to 1F. In each drawing, in order to make the individual layers and the individual members recognizable in the drawing, different scales are used for the individual layers and the individual members.

First, a glass substrate 1 is prepared. A photoresist 13a as a mask is formed on the surface, which is to face a liquid crystal, of the substrate 1. Specifically, in this embodiment, as shown in Figs. 1A and 1B, the photoresist 13a is formed on the glass substrate 1 so as to cover a region excluding display areas of liquid crystal devices. Additionally, the photoresist 13a may be formed, for example, by flexography. As will be described below, the region covered by the photoresist 13a constitutes the planar region.

As shown in Fig. 1C, the regions, not covered by the photoresist 13a, of the surface of the glass substrate 1 are then roughened. The roughening treatment for the surface of the glass substrate 1 will be described below.

Next, as shown in Fig. 1D, the photoresist 13a is removed. Consequently, the region which has been provided with the photoresist 13a in one of the surfaces of the glass substrate 1 constitutes a planar region 14 and the other region constitutes a roughened region 11.

As shown in Fig. 1E, a reflective metal film 12a is then formed on

the entire surface of the glass substrate 1 having the planar region 14 and the roughened region 11. The metal film 12a is composed of, for example, an elemental metal, such as aluminum or silver, or an alloy containing aluminum, silver, chromium, or the like as the principal ingredient.

Next, as shown in Fig. 1F, the metal film 12a is removed excluding regions corresponding to display areas (i.e., roughened regions 11) and portions in the planar region 14. In order to pattern the metal film 12a, for example, photolithography may be used. In the metal film 12a thus patterned, the metal film lying in the roughened region 11 constitutes a reflecting film 12. Peaks and valleys which are affected by the microscopic peaks and valleys of the roughened region 11 are formed on the surface of the reflecting film 12. That is, a scattering structure for reflecting and appropriately scattering light reaching the reflecting film 12 is formed. On the other hand, the metal film in the planar region 14 is patterned, for example, in a shape shown in Fig. 2, and is used as an alignment mark 15. Fig. 2 is an optical micrograph of the alignment mark 15 formed in the planar region 14. The alignment mark 15 is used for aligning the individual glass substrates at predetermined positions when the glass substrate 1 in this embodiment and the other glass substrate are bonded together.

After the process described above, electrodes for applying an electric field to the liquid crystal, alignment films, etc. are formed on the surface of the glass substrate 1 provided with the reflecting films 12 and the alignment marks 15. A frame-like sealant is then

formed so as to surround the region corresponding to the display area of each liquid crystal device. The glass substrate 1 and the other glass substrate are bonded together with the sealant therebetween. The liquid crystal is injected into regions surrounded by the sealant between the pair of substrates thus bonded, and then the individual liquid crystal devices are separated.

In the step of bonding the pair of glass substrates to each other, the alignment marks 15 are used. Specifically, alignment marks corresponding to the alignment marks 15 formed on the glass substrate 1 are formed on the other glass substrate opposed to the glass substrate 1. Both glass substrates are bonded together with the alignment marks on both glass substrates being matched with each other. Herein, in the bonding step, generally, alignment marks are recognized by light reflected from the alignment marks. When such a method is used, if the surface of the glass substrate on which the alignment marks are formed is roughened, the reflected light scatters in a direction other than the recognition direction, resulting in a difficulty in recognizing the alignment marks. In contrast, in accordance with the substrate for the liquid crystal device of the present invention, since the alignment marks 15 are formed in the planar region 14, such a problem does not arise.

A-2: Second Embodiment

Next, a method for fabricating a substrate for a liquid crystal device in a second embodiment of the present invention will be described with reference to Figs. 3A to 3F.

In this embodiment, as shown in Figs. 3A and 3B, a cylindrical photoresist 13a is formed as a mask at 2 positions on the surface of a glass substrate 1. As shown in Fig. 3C, in a manner similar to that in the first embodiment, a region other than the regions covered by the photoresist 13a is roughened and the photoresist 13a is removed. Consequently, as shown in Fig. 3D, 2 circular regions which had been covered by the photoresist 13a on the surface of the glass substrate 1 constitute planar regions 14, and the other region constitutes a roughened region 11.

Next, in a manner similar to that in the first embodiment, as shown in Fig. 3E, a metal film 12a is formed on the entire surface of the glass substrate 1. The metal film 12a is then removed excluding regions corresponding to display areas as well as minute portions in the planar region 14. In the metal film 12a thus patterned, the metal film in the region corresponding to the display area constitutes a reflecting film 12 and the metal film 12a in the planar region 14 is patterned, for example, in the shape shown in Fig. 2 to form an alignment mark 15. Since the subsequent fabrication steps are the same as those in the first embodiment, description thereof will be omitted.

Additionally, although the photoresist is used as the mask in this embodiment and in the first embodiment described above, a resin material, such as an epoxy resin, may be used as the mask instead of the photoresist.

A-3: Third Embodiment

Next, a method for fabricating a substrate for a liquid crystal

device in a third embodiment of the present invention will be described with reference to Figs. 4A to 4F.

In this embodiment, as shown in Figs. 4A and 4B, a laminated film 13b as a mask is attached to the center of each side of a glass substrate 1. Herein, the laminated film 13b which is cut into a rectangle of 8 mm × 45 mm is used.

As shown in Fig. 4C, in a manner similar to that in the first embodiment, a region other than the region covered by the laminated film 13b is then roughened, and the laminated film 13b is removed (Fig. 4D). Consequently, four rectangular regions of the surface of a glass substrate 1 which had been covered by the laminated films 13b constitute planar regions 14 and the other region constitutes a roughened region 11.

Next, in a manner similar to that in the first embodiment, a reflecting film 12 is formed in areas corresponding to display areas in the roughened region 11, and alignment marks 15 are formed in portions of the planar region 14 (Figs. 4E and 4F). Since the subsequent fabrication steps are the same as those in the first embodiment described above, description thereof will be omitted.

B: Method of Fabricating Planar Region and Roughened Region

Next, specific methods for fabricating the planar region 14 and the roughened region 11 will be described.

B-1: First Fabrication Method

A first method for forming the planar region 14 and the roughened region 11 on a glass substrate 1 will be described with reference to Figs. 5A to 5E. Herein, an aluminosilicate glass substrate is used as

the glass substrate 1.

Fig. 5A schematically shows the structure of a section of the glass substrate 1. As shown in the drawing, the glass substrate 1 contains a network former 2 and a network modifier 3 located so as to fill spaces between the network of the network former 2. The network former 2 is composed of, for example, a copolymer of silica and aluminum oxide, and the network modifier 3 is composed of, for example, magnesium oxide.

First, before the mask as described in any one of the above embodiments (the photoresist 13a, the laminated film 13b, or the like in each embodiment) is formed, the glass substrate 1 is subjected to etching, which also serves to clean the substrate. Specifically, for example, the glass substrate 1 is immersed in an approximately 5 wt% hydrofluoric acid solution for approximately 5 seconds at 25°C.

Next, as shown in Fig. 5B, a mask 13 is formed at a predetermined position on the surface of the glass substrate 1 which has been uniformly etched.

The glass substrate 1 is then immersed in a 30 wt% hydrofluoric acid solution, in which aluminum oxide and magnesium oxide are supersaturated, for approximately 30 seconds at 25°C (hereinafter, this treatment is referred to as the "first etching"). In this treatment, the aluminum oxide in the supersaturated solution precipitates in portions in which aluminum oxide is located in the network former 2, and the magnesium oxide in the supersaturated solution precipitates in the portion in which magnesium oxide is located in the network modifier 3. As the result of the precipitation, as shown in Fig. 5C, a microscopic

network structure 10 is formed. On the other hand, portions comprising compositions which are not supersaturated in the treatment solution (i.e., compositions other than aluminum oxide and magnesium oxide) in the network former 2 and the network modifier 3 are corroded by hydrofluoric acid. Consequently, valleys 11a are formed in the region other than the region in which the network structure 10 is formed in the surface of the glass substrate 1. Fig. 6A is an optical micrograph showing the state of the surface of the glass substrate 1 in the region other than the region covered by the mask 13 at this stage. In the drawing, the dark portion corresponds to the network structure 10 and the light portion corresponds to the valley 11a.

As shown in Fig. 5D, the mask 13 is then removed. Since the region in which the mask 13 had been formed is not subjected to the first etching, the surface thereof is planar.

Next, the entire surface of the glass substrate 1 is uniformly etched (hereinafter, this treatment is referred to as the "second etching"). For example, a solution in which a 50 wt% hydrofluoric acid solution and a 40 wt% ammonium fluoride solution are mixed at a weight ratio of 1 to 3 is prepared, and the glass substrate 1 is immersed in the solution for approximately 20 seconds at 25°C. By such a treatment, the network structure 10 and microscopic protrusions formed in the valleys 11a are removed. Consequently, as shown in Fig. 5E, the region in which the mask 13 was not formed on the glass substrate 1 constitutes the roughened region 11 having smooth peaks and valleys. Fig. 6B is an optical micrograph showing the state of the surface of the glass

substrate 1 at this stage. As is also clear from this illustration, since the glass substrate 1 which has been subjected to the first etching is further subjected to the second etching, a smoother roughened surface is formed in comparison with the surface immediately after the first etching shown in Fig. 6A.

Fig. 7 is an optical micrograph showing the state of the surface of the glass substrate 1 after the second etching. From this illustration, it is also confirmed that the region A in which the mask 13 was formed constitutes a planar region 14 and the other region B constitutes the roughened region 11 having microscopic peaks and valleys.

Subjecting the glass substrate 1 to the second etching before the mask 13 is removed may be contemplated. However, in such a case, the region provided with the mask 13 is not subjected to the second etching, and the other region is etched. As a result, the difference in level between the planar region 14 and the roughened region 11 increases as the second etching advances. If the difference in level between the planar region 14 and the roughened region 11 in the glass substrate 1 is larger than the desired cell gap of the liquid crystal device, it is not possible to produce the desired cell gap by using the glass substrate 1.

In contrast, in this embodiment, since the entire surface of the glass substrate 1 is subjected to the second etching after the mask 13 is removed, it is possible to avoid an increase in the difference in level between the planar region 14 and the roughened region 11. Fig. 8 is a graph which shows measurement results of the surface profile (height) of the surface of the glass substrate 1 shown in Fig. 7. As

shown in Fig. 8, in the fabrication process described above, the difference in level between the planar region 14 and the roughened region 11 in the surface of the glass substrate 1 can be decreased to approximately 1 μm. Since the cell gap of a typical liquid crystal device is approximately 5 μm, the glass substrate 1 obtained by the above process can be used as a substrate for a typical liquid crystal device without any problems.

B-2: Second Fabrication Method

A second method for forming the planar region 14 and the roughened region 11 on a glass substrate 1 will be described with reference to Figs. 9A to 9E. Herein, a soda-lime glass substrate is used as the glass substrate 1.

Although the glass substrate 1 is the same as the glass substrate 1 in the first fabrication method in that the glass substrate 1 contains a network former 2 and a network modifier 3 located so as to fill spaces between the network of the network former 2 as shown in Fig. 9A, it differs from the glass substrate 1 in the first fabrication method in that the network former 2 is composed of silica and the network modifier 3 is composed of an alkali metal or an alkaline-earth metal.

First, before a mask 13 is formed in the region in which the planar region 14 is to be formed, the glass substrate 1 is subjected to etching, which also serves to clean the substrate. Specifically, the glass substrate 1 is immersed in a 5 wt% hydrofluoric acid solution for approximately 5 seconds at 25°C. Next, as shown in Fig. 9B, the mask 13 (a photoresist, a laminated film, or the like) is formed in the region

of the surface of the glass substrate 1 in which the planar region 14 is to be formed.

The glass substrate 1 is then immersed in a treatment solution containing 30 wt% of hydrofluoric acid and 45 wt% of ammonium hydrogen difluoride for approximately 15 seconds at 25°C. Herein, as shown in Fig. 9C, with respect to the compositions of the glass substrate 1, the dissolution rate of the network modifier 3 in the treatment solution is higher than the dissolution rate of the network former 2 in the treatment solution. Therefore, when the glass substrate 1 is immersed in the treatment solution, as shown in Fig. 9D, the region etched (i.e., the region not covered by the mask) becomes the roughened region in which peaks and valleys are formed in response to the shape of the network former 2. As shown in Fig. 9E, the mask 13 is then removed and the glass substrate 1 provided with the planar region 14 and the roughened region 11 can be obtained.

B-3: Third Fabrication Method

Next, a third method for forming the planar region 14 and the roughened region 11 on a glass substrate 1 will be described with reference to Figs. 10A to 10F. Herein, a soda-lime glass substrate is used as the glass substrate 1.

First, a stainless steel plate 17 provided with openings is placed on one surface of the glass substrate 1. The stainless steel plate 17 serves as a mask, and as shown in Figs. 10A and 10B, openings are provided in regions in which roughened regions 11 are to be formed.

Next, as shown in Fig. 10C, a large amount of abrasive powder 18 is

sprayed to the surface of the glass substrate 1 through the stainless steel plate 17. In this process, many recesses are formed in the regions corresponding to the openings of the stainless steel plate 17 in the surface of the glass substrate 1 due to impact with the abrasive powder 18. Since the abrasive powder 18 does not impact the region covered by the stainless steel plate 17, the planar surface remains as it is.

Next, the glass substrate 1 is cleaned. That is, the abrasive powder 18 sprayed to the glass substrate 1 and glass powder produced by the impact of the abrasive powder 18 are removed. The glass substrate 1 is then immersed in a predetermined treatment solution, and the entire surface of the glass substrate 1 is uniformly etched. As the predetermined treatment solution, for example, a treatment solution in which hydrofluoric acid (50 wt%) and an ammonium fluoride solution (40 wt%) are mixed at a weight ratio of 1 to 3 is used.

By the treatment described above, as shown in Fig. 10D, the glass substrate 1 in which the planar region 14 and the roughened region 11 are selectively formed is obtained. In a manner similar to that in the first fabrication method, as shown in Fig. 10E, a metal film 12a is then formed on the glass substrate 1. The metal film 12a is patterned and a reflecting film 12 and an alignment mark 15 are formed as shown in Fig. 10F.

As described above, in the first to third fabrication methods, the valleys of the roughened region 11 are formed by removing many microscopic regions in the surface of the glass substrate 1. As a

result, in the glass substrate 1 obtained by each fabrication method described above, the tops of the peaks in the roughened region 11 are lower than the plane including the planar region 14.

The conventional glass substrate used as a substrate for a liquid crystal device has a roughened region in which peaks and valleys are formed regularly. That is, as shown in Fig. 11, peaks having substantially the same height (or valleys having substantially the same depth) are formed in the roughened surface of the conventional glass substrate, and the individual peaks are formed with the same space therebetween. Consequently, when light A and light B which are parallel to each other enter into the roughened surface with a certain angle, the reflected light path of the light A which reflects in the peak is shorter than the reflected light path of the light B which reflects in the valley by (i + j). Since interference of light is generated due to such an optical-path difference, unnecessary coloring may occur in an image to be displayed.

In contrast, in the substrate for the liquid crystal device in accordance with the present invention, such a problem does not arise. That is, in the first and second fabrication methods, an irregular roughened surface corresponding to the shape of the network former 2 is formed on the glass substrate 1, and in the third fabrication method, an irregular roughened surface in response to the impact of the abrasive powder 18 is formed on the glass substrate 1. Therefore, in any one of the first, second, and third fabrication methods, the roughened region 11 is formed in which the individual peaks have different heights and

the individual valleys have different depths, and also the distance between the top of one peak and the top of an adjacent peak differs for each peak. As a result, satisfactory scattering characteristics can be imparted to the reflecting film 12 formed in the roughened region 11.

Although such a roughening region 11 is formed on the surface of the glass substrate 1, the surface of the glass substrate 1 in the planar region 14 is planar. Therefore, elements which are desirably formed on the plane, such as alignment marks 15, can be formed in the planar region 14.

C: Reflection Property of Reflecting Film

The reflection property of the glass substrate 1 formed by any one of the fabrication methods described above in which a reflecting film is formed in the roughened region will be described.

Fig. 12 shows a measuring device for measuring reflection properties. As shown in the drawing, in the measuring device, light 5 is emitted to the glass substrate 1 at 25° to the normal to the glass substrate 1. The intensity of light reflected from a reflecting film 12 on the glass substrate 1 is measured by a photomultimeter 6. The intensity of reflected light is measured by the photomultimeter while changing an angle θ to the normal to the glass substrate 1. Additionally, in the measurement, in order to simulate the use as a liquid crystal device, as shown in Fig. 12, the measurement was carried out in a state in which a glass substrate 2 (approximately 0.7 mm thick) composed of the same material as that of the substrate 1 was opposed to the surface of the glass substrate 1 provided with the reflecting film

and a liquid crystal layer 8 was interposed between the two substrates.

The measurement was carried out with respect to a plurality of glass substrates 1 which were fabricated by the first or second fabrication method under different conditions, such as types of etching treatment solutions and etching periods of time. The measurement was also carried out with respect to a plurality of glass substrates 1 fabricated by the third fabrication method under different conditions, such as particle sizes and numbers of the abrasive. As a result, reflection properties shown in Fig. 13 were obtained as typical reflection properties of the glass substrate 1 obtained by each fabrication method. Fig. 13 is a graph which shows the relationship between the angle θ of the photomultimeter and the intensity of reflected light measured by the photomultimeter. Additionally, numerals 17 and 18 in Fig. 13 represent reflection properties of reflectors which are commercially available, for comparison. However, this type of reflector is attached to a substrate after a liquid crystal is sealed between a pair of substrates. That is, it is to be noted that such a reflector is not provided on the side of the liquid crystal layer as in the embodiments, but is provided on the opposite side.

As shown in the drawing, in accordance with the glass substrates 1 obtained by the fabrication methods described above, satisfactory reflection properties which are equal to or greater than those of the conventional reflectors can be obtained by the simple fabrication process. Specific examples are described below.

First, with respect to a reflection property 19 shown in Fig. 13,

the reflected light having higher intensity is observed in most of the angle corresponding to the viewing angle when used as a liquid crystal device in comparison with the commercially available reflectors. Therefore, in the liquid crystal device which uses a substrate for the liquid crystal device obtained by the glass substrate 1 having the reflection property 19, satisfactory display characteristics can be obtained.

Next, with respect to reflection properties 20 and 23 in Fig. 13, reflected light having high intensity is observed in a relatively narrow range in comparison with the other reflection properties. Herein, in a liquid crystal device using a STN (super twisted nematic) liquid crystal mode, the viewing angle in which satisfactory display characteristics having a high contrast ratio can be obtained is limited to a relatively narrow angle in principle. That is, it is not required that light having high intensity be reflected to a wider angle than the viewing angle in which satisfactory display quality is obtained. Therefore, the glass substrate 1 having the reflection property 20 or 23 in Fig. 13 is suitable for a substrate for the liquid crystal device using the STN liquid crystal mode.

With respect to reflection properties 21 and 22 in Fig. 13, reflected light having a predetermined intensity is observed in a relatively broad range in comparison with the other reflection properties. Herein, in a liquid crystal device using a TN (twisted nematic) liquid crystal mode or a SH (superhomeotropic) liquid crystal mode, a relatively broad viewing angle can be obtained. Therefore, the

glass substrate 1 having the reflection property 21 or 22 in Fig. 13 is suitable for a substrate for the liquid crystal device using the TN liquid crystal mode or the SH liquid crystal mode. Additionally, such reflection properties of the glass substrates 1 appear to be equal to or lower than the reflection property 17 or 18 of the conventional substrate for the liquid crystal device shown in Fig. 13. However, in Fig. 13, the conventional reflectors used for comparison are located opposite to the liquid crystal as described above. When such reflectors are used, due to the optical-path difference between the light passing through the liquid crystal layer and reflected by the surface of the substrate for the liquid crystal device and the light which reaches the reflecting film and is reflected, a double image may be produced in the displayed image. In contrast, in accordance with the substrate for the liquid crystal device of the present invention, since the reflecting film is formed on the liquid crystal side, such a problem does not arise. Therefore, overall, the glass substrate having the reflection property 21 or 22 in Fig. 13 is more suitable for the substrate for the liquid crystal device.

Next, with respect to the individual glass substrates 1 having the reflection properties (numerals 19 to 23), the present inventor measured the individual characteristic values which represent the surface profile in the roughened region using a surface roughness tester. Description of the individual characteristic values measured will be given.

(1) Maximum Height Ry

The maximum height Ry is a characteristic value which represents a

difference in level between the top of the highest peak in the roughened region and the bottom of the deepest valley in the same region.

(2) Arithmetic mean roughness Ra

The arithmetic mean roughness Ra is an average value of the total of absolute values of deviations of the curve to be measured, which represents the surface profile in the roughened region, from a predetermined mean line.

(3) Ten-point Average Roughness Rz

The ten-point average roughness Rz is the sum of the average of the heights of the tops of the 5 highest peaks, viewed from a predetermined mean line, and the average of the depths of the bottoms of the 5 deepest valleys.

(4) Mean Wavelength Sm

The mean wavelength Sm is a characteristic value which represents a mean wavelength of the period of the peaks or the valleys exceeding a predetermined dead band with a mean line as the central line. Additionally, in this embodiment, a banded region having a width of 1% of the maximum height Ry with the mean line as the central line is set as the dead band to measure the mean wavelength.

Additionally, the individual characteristic values are described in detail in JIS (Japanese Industrial Standards) B 0601-1994, and in ISO (International Organization for Standardization) 468-1982, ISO 3274-1975, ISO 4287/1-1984, ISO 4287/2-1984, and ISO 4288-1985.

The individual characteristic values were measured with respect to the glass substrate 1 having the reflection property 19 shown in Fig. 13.

The maximum height Ry was 0.75 μm, the arithmetic mean roughness Ra was 0.09 μm, the ten-point average roughness Rz was 0.7 μm, and the mean wavelength Sm was 17 μm.

With respect to the individual characteristic values of the glass substrate 1 having the reflection property 20, the maximum height Ry was 0.60 μm, the arithmetic mean roughness Ra was 0.08 μm, the ten-point average roughness Rz was 0.45 μm, and the mean wavelength Sm was 11 μm. As described above, the glass substrate 1 having the reflection property 20 is suitable for the liquid crystal device using the STN liquid crystal mode. Based on the above, it is preferable that in the roughened region of the substrate used for the liquid crystal device using the STN liquid crystal mode, the maximum height Ry and Rz be minimized as much as possible. Furthermore, by decreasing the arithmetic mean roughness Ra, thickness deviations of the liquid crystal layer corresponding to in-plane undulations can be suppressed.

With respect to the individual characteristic values of the glass substrate 1 having the reflection property 21, the maximum height Ry was 1.75 μm, the arithmetic mean roughness Ra was 0.24 μm, the ten-point average roughness Rz was 1.57 μm, and the mean wavelength Sm was 22 μm.

With respect to the individual characteristic values of the glass substrate 1 having the reflection property 22, the maximum height Ry was 0.95 μm, the arithmetic mean roughness Ra was 0.12 μm, the ten-point average roughness Rz was 0.85 μm, and the mean wavelength Sm was 11 μm. As described above, the glass substrate 1 having the reflection property 22 is suitable for the liquid crystal device using the TN or SH liquid

crystal mode. Based on the above, it is preferable that in the roughened region of the substrate used for the liquid crystal device using the TN liquid crystal mode or the SH liquid crystal mode, the ten-point average roughness Rz be relatively increased or the mean wavelength Sm be relatively decreased.

With respect to the individual characteristic values of the glass substrate 1 having the reflection property 23, the maximum height Ry was 0.98 μm, the arithmetic mean roughness Ra was 0.13 μm, the ten-point average roughness Rz was 0.80 μm, and the mean wavelength Sm was 42 μm.

As described above, the reflection property of the reflecting film formed in the roughened region is determined depending on the surface profile of the roughened region formed in the substrate (glass substrate 1) of the liquid crystal device. Consequently, the various conditions in the individual fabrication methods are preferably selected so that the surface profile of the roughened region is determined depending on the liquid crystal mode to be used.

D: Modified Examples

Although the embodiments of the present invention were described in the above, the individual embodiments are only examples, and various modifications can be made within the scope not deviating from the object of the present invention. For example, modified examples described below may be referred to.

(1) Although the alignment mark used for aligning the glass substrate with the other substrate is formed in the planar region of the glass substrate 1 in the embodiments described above, alignment marks

used for the applications described below may also be formed. That is, alignment marks used for forming switching elements, pixel electrodes, etc., for forming pigmented layers, protective layers, shading layers, etc. of color filters, for applying alignment films, for printing sealants, for cutting panels, for mounting a driver, and so on may be formed in the planar region.

What is formed in the planar region is not limited to the alignment marks. That is, various types of elements to be formed on a planar surface may be formed in the planar region. For example, process control marks may be formed in the planar region. The process control marks are marks used for controlling the fabrication processes for liquid crystal devices, and examples thereof are lot numbers, model numbers, and treatment conditions in various fabrication processes, etc. symbolized as marks. The process control marks may be digitized, encoded into bar codes, or printed in the form of two-dimensional bar codes, such as verified-codes.

Moreover, what is formed in the planar region is not limited to marks. For example, in the substrate used for an active matrix liquid crystal device, wiring, such as scanning lines and data lines, switching elements, such as TFTs, and TFDs, and so on may be formed in the planar region. Furthermore, terminals of a semiconductor integrated circuit for driving a liquid crystal may be formed in the planar region, and a sealant may be formed. Additionally, the shape of the planar region is not limited to that shown in the first to third embodiments, and the shape corresponding to the shape of the element which is formed on the

surface thereof is preferably selected.

(2) In the embodiments described above, although the alignment mark 15 is composed of the metal film 12a for forming the reflecting film 12, the alignment mark 15 may be composed of a material for forming other layer or member to be formed on the glass substrate 1. That is, the alignment mark may be composed of chromium used for forming a shading film, a pigment resist used for forming a color filter, a metal mainly composed of tantalum used for forming a switching element, or the like. The same as the above applies to the process control marks.

E: Structure of Liquid Crystal Device

Next, examples of the structures of liquid crystal devices using the substrates for liquid crystal devices in the individual embodiments described above will be described. Examples of the structures of passive matrix liquid crystal devices will be described below.

(1) Reflective Liquid Crystal Device

Fig. 14 is a sectional view which shows a structure of a reflective liquid crystal device using a substrate for a liquid crystal device in accordance with the present invention. As shown in the drawing, in the liquid crystal device, a front substrate 100 and a back substrate 200 are bonded together with a sealant 300 therebetween, and a liquid crystal 400 is enclosed between both substrates. The liquid crystal 400 is, for example, a nematic liquid crystal having a predetermined angle of twist. In Fig. 14, a substrate for a liquid crystal device in accordance with the present invention is used for the back substrate 200.

A shading layer 101, a pigmented layer 102, and a protective layer

103 are formed on the interior surface of the front substrate 100 (on the side of the liquid crystal 400). In the pigmented layer 102, a resin material pigmented in any one of R (red), G (green), and B (blue) is arranged in a predetermined pattern. The shading layer 101 shades the spaces between the pigmented patterns by the pigmented layer 102. The protective layer 103 protects the pigmented layer 102 and also planarizes the steps between the individual pigmented patterns. Furthermore, a plurality of transparent electrodes 105 are formed with an adhesion-improving layer 104 which covers the protective layer 103 serving as an underlayer. The transparent electrodes 105 are striped electrodes extending in a predetermined direction, and are composed of a transparent conductive material, such as ITO. The surface of the adhesion-improving layer 104 provided with the transparent electrodes 105 is covered by an alignment film 106. The alignment film 106 is an organic thin film composed of a polyimide or the like, and is subjected to rubbing treatment for defining the alignment direction of the liquid crystal in the absence of an applied voltage. A retardation film 107 and a polarizer 108 are arranged on the exterior surface of the front substrate 100.

On the other hand, the back substrate 200 which is the substrate for the liquid crystal device in accordance with the present invention is provided with a roughened region 201 and a planar region 202 on the interior surface. A plurality of reflecting electrodes 203 are formed in the roughened region 201. Specifically, the individual reflecting electrodes 203 are striped electrodes extending in a direction

orthogonal to the extending direction of the transparent electrodes 105. The surface of the back substrate 200 provided with the reflecting electrodes 203 is covered by an alignment film 204 which is similar to the alignment film 106.

In such a structure, external light entering from the side of the front substrate 100 passes through the polarizer 108, the retardation film 107, the front substrate 100, the pigmented layer 102, the liquid crystal 400, etc. in that order, is reflected by the reflecting electrodes 203, and is emitted from the side of the front substrate 100 after passing through the channel in reversed order. Thus, reflective display is performed. The alignment state of the liquid crystal 400 is controlled in response to a voltage applied between the transparent electrodes 105 and the reflecting electrodes 203, and thus the bright state and the dark state in the display image can be controlled.

Although the passive matrix liquid crystal device is shown in Fig. 14, the present invention is also applicable to an active matrix liquid crystal device provided with switching elements, such as TFTs and TFDs. In such a case, the reflecting electrodes 203 in Fig. 14 are formed, for example, in a rectangular shape and are connected to lines via the switching elements. Additionally, in a liquid crystal device in which TFTs are provided as switching elements, it is not required to pattern the transparent electrodes 105 formed on the front substrate 100.

In such a case, various types of wiring, the switching elements, etc. are preferably formed in the planar region 202 of the back substrate 200 which is the substrate for the liquid crystal device in

accordance with the present invention. Herein, "wiring" conceptually includes terminals provided in a semiconductor integrated circuit for driving a liquid crystal, etc. as well as scanning lines and data lines.

The elements to be formed in the planar region 202 are formed in a similar process to that shown in Figs. 1E and 1F in which the alignment mark 15 is formed by patterning the metal film 12a. That is, after a predetermined film (e.g., a film composed of a transparent conductive material) is formed on the back substrate 200 including the planar region 202, the film is subjected to etching, photolithography, or the like, and thus lines, etc. patterned in a desired shape are formed in the planar region 202.

The elements formed on the back substrate 200 are not limited to the above. For example, the sealant 300 shown in Fig. 14 may be formed in the planar region 202 of the back substrate 200.

(2) Transflective Liquid Crystal Device

In the reflective liquid crystal device shown in Fig. 14, although operation at low power consumption is enabled, the display becomes dark when there is not a sufficient amount of external light. In the transflective liquid crystal device described below, reflective display is performed in the presence of sufficient external light, and transmissive display is performed in the absence of sufficient external light.

Fig. 15 is a sectional view which schematically shows the structure of a reflective liquid crystal device using a substrate for a liquid crystal device in accordance with the present invention. In the liquid

crystal device shown in Fig. 15, the same numerals as those of the liquid crystal device shown in Fig. 14 are assigned to the same portions, and description thereof will be omitted.

In a roughened region 201 of the internal surface of a back substrate 200 (on the side of a liquid crystal 400), a reflecting film 205 provided with openings 205a is formed. On the surface of the back substrate 200 provided with the reflecting film 205, a pigmented layer 206 and a shading layer 207 are formed. In Fig. 15, as the shading layer 207, a laminate comprising pigmented layers 206 of three colors of R, G, and B is used. Instead of this, the shading film 207 may be provided separately using resin black or multilayered chromium. A protective layer 208 which covers the pigmented layer 206 and the shading layer 207 is used for planarizing peaks and valleys on the pigmented layer 206 formed in response to the roughened region 201 on the back substrate 200. Furthermore, a plurality of transparent electrodes 210 are formed with an adhesion-improving layer 209 which covers the protective layer 208 serving as an underlayer. The individual transparent electrodes 210 extend in a direction orthogonal to transparent electrodes 105 on a front substrate 100, and are composed of, for example, ITO.

On the other hand, a retardation film 211 and a polarizer 212 are attached to the external surface of the back substrate 200. A backlight 500 is arranged at the exterior of the polarizer 212. The backlight 500 includes a fluorescent tube 501 as a light source and a light guide plate 502 for guiding light from the fluorescent tube 501 to the entire

surface of the back substrate 200. As the backlight 500, a LED (light-emitting diode), EL (electroluminescence), etc. may be used in addition to the above.

In such a structure, light entering from the side of the front substrate passes through the polarizer 108, the retardation film 107, the liquid crystal 400, the transparent electrodes 210, and the pigmented layer 206 to reach the reflecting film 205, and is reflected by the reflecting film 205, and then is emitted from the side of the front substrate 100 after passing through the channel in reversed order.

On the other hand, light emitted from the backlight 500 passes through the polarizer 212 and the retardation film 211 to become predetermined polarized light, which passes through the openings 205a provided in the reflecting film 205, the pigmented layer 206, the liquid crystal 400, the front substrate 100, the retardation film 107, and the polarizer 108. Thus, transmissive display is performed.

Additionally, in Fig. 15, although transmissive display is implemented by providing the openings 205a for the individual pixels, the following method may be employed. That is, instead of providing the openings 205a, the thickness of the reflecting film 205 may be set at 15 to 20 nm so that the reflecting film 205 acts as a transflector having a reflectance of approximately 85% and a transmittance of approximately 10%.

Although the passive matrix liquid crystal device is shown in Fig. 15, the present invention is also applicable to an active matrix liquid crystal device provided with switching elements, such as TFTs or TFDs.

In such a case, the transparent electrodes 105 in Fig. 15 are formed, for example, in a rectangular shape, and are connected to lines through the switching elements. Additionally, in the liquid crystal device in which TFTs are provided as switching elements, it is not required to pattern the transparent electrodes 210. In such a case, the same as the above, various types of lines, etc. are preferably formed in the planar region 202 of the back substrate 200.

In the liquid crystal devices described above in (1) and (2), an alignment mark formed on the back substrate 200 is used when the back substrate 100 and the front substrate 200 are bonded together. Since the alignment mark is formed in the planar region 202 of the back substrate 200, the back substrate 200 and the front substrate 100 can be aligned with each other with high accuracy. As a result, the occurrence of a double image and smear is suppressed and display with a high contrast ratio can be obtained.

F: Electronic Apparatus

Next, electronic apparatuses using the liquid crystal devices shown in the above embodiments will be described. As described above, the liquid crystal devices are suitable for mobile apparatuses which can be used under various environments and also require low power consumption.

First, Fig. 16A is a perspective view of a mobile information apparatus as an example of the electronic apparatus. As shown in the drawing, a liquid crystal device 121 in accordance with the present invention is provided on the upper side of a mobile information apparatus body 122, and an input unit 123 is provided on the lower side.

In general, a touch panel is provided on the front of the display section of this type of mobile information apparatus. Therefore, conventionally, even in the case of a mobile type device, a transmissive liquid crystal device is often used for the display section. However, in the transmissive liquid crystal device, since a backlight is always used, the power consumption is increased and the battery life is short. In contrast, in the liquid crystal device in accordance with the present invention, regardless of reflective type or transflective type, bright and vivid display can be obtained, and thus it is suitable for the mobile information apparatus.

Next, Fig. 16B is a perspective view which shows the structure of a cellular telephone as an example of the electronic apparatus. As shown in the drawing, a liquid crystal device 124 in accordance with the present invention is provided on the upper section of the front surface of a cellular telephone 125. Cellular telephones are used under every environment, and are often used in automobiles in particular. However, it is very dark in the nighttime in a car. Therefore, as the display device, a transflective liquid crystal device in which reflective display with low power consumption is mainly used and transmissive display using auxiliary light is used as necessary, i.e., the liquid crystal device shown in Fig. 15, is preferably used. In the liquid crystal device 124, regardless of reflective display or transmissive display, high-quality display with a high contrast ratio, which is brighter than the conventional liquid crystal device, can be obtained.

Next, Fig. 16C is a perspective view which shows the structure of a

watch as an example of the electronic apparatus. As shown in the drawing, a liquid crystal display device 126 in accordance with the present invention is provided in the center of a watch body 127. High-grade appearance is important in the application to watches. The liquid crystal device 126 is bright and has a high contrast, and also is not colored greatly because a change in characteristics due to the wavelength of light is decreased. Therefore, display with greatly high-grade appearance can be obtained in comparison with the conventional liquid crystal device.